27 November 1957

RAINBOW PROGRAM - PHASE II

1. At various meetings on the RAINBOW Program starting with the meeting on 3 October 1957 in Cambridge, Massachusetts, there has been discussion of possible design approaches to a new aircraft and of experiments that might be done in the relatively near future to evaluate various approaches. Although some experiments are going forward, no orderly list and schedule of experimental work has been drawn up so far as I am aware, and I am not satisfied that responsibilities for the performance of this work are clearly understood by all concerned. Accordingly, I believe it essential that a firm schedule be established, and written down, so we can have some idea when results will be in hand and when it will be possible to define and evaluate the one or more most promising design approaches. The following notes are intended as a first step towards establishing the schedule requested above.

2. In all of the discussions of this problem, essentially four techniques have been mentioned as the means of reducing reflectivity.

a. For the higher frequencies, the use of completely reflecting outer surfaces so configured that radiation is reflected off at innocent angles.

b. The absorption of radiation, by either thin or thick layers of absorptive material or by such techniques as externally disposed dipoles currently employed on the U-2.

c. With special reference to low frequencies, the graduation of the conductivity of a structure so as to render an edge or surface "soft" electrically, thereby avoiding a discontinuity which would give rise to a reflection. (This is really a subcase under b.)

d. The use of highly transparent structures with very small return reflection.

It is hard to believe that there can be any techniques which do not involve either the innocent reflection, absorption, or onward transmission of

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radiation. Accordingly, a given design approach must involve some combination of the four techniques listed above.

3. There is presumably no doubt that the specular reflection of high frequency radiation from smooth conducting surfaces is calculable, and that, if corners are eliminated aircraft configurations can be designed from which there will be no specular return reflection. It would appear, then, that the questions concerning the use of reflective techniques which require further investigation are those having to do with: (a) Non-specular reflection, and (b) Compromises that might have to be made to achieve aerodynamically acceptable configurations. As an example of the former,
1.1.4 is it certain that a fuselage built with flat sides inclined at properly selected angles would give rise to ~~more~~ no non-specular back reflection from its sharp convex corners? As an example of the latter, how great a penalty would be paid for various degress of rounding of such sharp convex corners? Hopefully such questions can be answered by the measurement of return from scale models.

4. In discussion of the higher frequency problem (X, S, and L bands possibly down to 500 mgs.) it has appeared that major reliance would be placed on a combination of reflection and absorption. If heavy reliance is placed on a reflective configuration, sharply angular shapes will be costly in terms of performance and some reliance will probably have to be placed on localized absorption. Moreover, if wings are of composite construction with central metal panels but leading and trailing edges of plastic, absorptive protection will be necessary at the edges of
1.3 the metal panels. A central question therefore is whether any lightweight and extremely broad-banded reflective materials are available or can be developed. The term "broad-banded" is here meant to cover, at a minimum, X plus S plus L bands. Naturally, bulk is undesirable but may have to be accepted whereas excessive weight is unacceptable.

5. Still on the high frequency problem, a second major question concerns the reflectivity of various nonconductive materials, as a function
1.2 of thickness. One structural approach in those areas where reliance is to be placed on absorption would be to build wings and fuselage of fiberglass (or other similar high-strength plastic) with relatively thick, stressed,

outer shell and leave space for (if necessary) bulky absorbent material immediately inside the shell to protect reflective metal structures such as the engine. A different approach (involving what has been called by Dr. Purcell a "squid" structure) might be to have an extremely thin non-conducting outer skin of some such material as figerglass or mylar, which would be stressed in tension but not in compression, with no structural absorptive material immediately beneath this thin skin covering the main structural spars as well as engine and other metal components. The relative advantage of different structural designs of this character cannot be weighed without accurate information as to the reflectivity of non-conductors or various materials and thicknesses.

6. In conjunction with reliance on reflection and absorption to cut down the reflectivity of major structural elements, it might be feasible to build parts of the aircraft entirely of non-conducting materials. The wings might be treated in this manner if an important advantage could thereby be derived. Or, the main structure might take the form of a high
1.2 aspect-ratio flying wing with tail surfaces (vertical and horizonal stabilizers) supported by a boom and the whole empennage made of plastic. The value of these approaches depends, of course, entirely on the reflectivity of the available materials, especially at higher frequencies. In particular, it is important to determine how much is gained by a combination of reflective shape and non-conducting material.

7. Urgently needed as a part of the general study of absorption is an investigation of the technique that has been proposed for rendering edges and surfaces electrically "soft" and thereby achieving very broad-banded absorption of radiation. The application of this technique has been most seriously considered in the form of the composite wing referred to
1.1.3 above. Another possible application might be to the fuselage, employing one of the structural approaches outlined in paragraph 5. above, although
1.1.2 the infeasibility of provision for a depth of three feet of absorbent material over the fuselage would presumably rule out this application for low frequency protection. The most useful test of this technique would presumably be an experiment with a scale model of a wing-like member. Meanwhile, however, work is going forward on the means of "softening" a structural edge, especially through the use of spiral antennae.

8. Assuming that the "softening" technique will be successful in reducing the reflectivity of wings and perhaps other outlying structural members to low frequency radiation, there remains the more difficult part of the whole problem which is the reduction of the return of low frequency radiation from the fuselage. An investigation that is going forward here is of the use of antennae parallel to the fuselage in extension
1.1.1 of the technique currently employed on the U-2. Even if adequate broad-banding (say up to 500-600 mgs) can be achieved in this manner, however, there is evidence from recent operations that the 12db reduction so far achieved with the U-2 is inadequate. Other solutions are being studied
25X1A at [redacted] I am left with the conviction that this is the area in which the least progress has been made and in which we can have the lowest confidence that we are on the right track.

9. The foregoing review suggests the following list of experiments and investigations to be carried out:

3.1 a. Measurement at one-tenth of scale of the reflectivity in S-band of models built of perfectly reflective materials but configured to test, first, an ideally reflective configuration and, second, various compromises of the ideal configuration.

1.3 b. The investigation and testing of lightweight absorptive materials up to, say, one-foot thickness, effective in X, S and L bands to as low a frequency as possible.

1.2 c. Calculation and if necessary actual measurement of the reflectivity of plastic structures, as a function of thickness and as a function of frequency. This should cover forward reflection as well as return reflection since fluttar techniques cannot entirely be disregarded.

1.1.3 d. Measurement of the return, at various aspects, from a wing-like structure of composite construction with central metal panel and electrically "softened" edges; the measurement to be done on scale models to simulate both low and high frequencies.

1.1.1 e. Scale model tests of multiple parallel external antennae designed to absorb low frequency radiation.

10. My impression of the status of the above experimental work and responsibility is as follows:

a. This work is underway at Westinghouse with a rough scale model based on one displayed at the October 3rd meeting. An additional model should probably be developed based on a high aspect-ratio flying wing with plastic empennage. First report by Westinghouse is due by 4 December.

b. We are still, of course, working vigorously on this problem in our effort to have improved RAINBOW material for the U-2 by next spring. At the moment, however, our progress is extremely discouraging. I have the distinct impression there is a tendency to assume that it is not difficult to devise highly effective lightweight absorbents at least for higher frequencies but that because this is assumed to be manageable, nobody is doing anything about it. Do we really know that moderately thin but lightweight absorbents of high efficiency are available?

c. I am told that this is a matter of calculation and that no experimental work is required. At the same time, I am confused by the estimated figures that are quoted to me. If a completely plastic aircraft would give 20 db less return than a metal aircraft of the same size, I take it that smaller structures such as the empennage would, if made of plastic, give rise to relatively little reflection. Is this conclusion valid? Do we have to try to combine the use of non-conducting materials with innocent specular reflection?

d. I am aware of very interesting work going forward in the Technical Staff in Cambridge on the technique of softening an edge but I am not clear that anybody has set in motion the construction of a model panel with which to test this theory macroscopically. Moreover, I understood that an edge could be softened very effectively with a graduated resistance. If the latter is correct should we not proceed at once to test the effectiveness of the "softening" without waiting until we perfect the exact technique of "softening"?

e. This is one experiment we should be able to do in a very few days at Lincoln. The real question that requires discussion in my view is what other techniques of low frequency absorption we should investigate. Fortunately, [redacted] is apparently concentrating on this problem and something useful may be forthcoming from there. 25X1A